# Cosmological constraint from QSO spatial power spectrum

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**Abstract.** In this paper we consider constraints on the cosmological density parameters from the spatial power spectrum of QSOs. We first review an analytic approach to the spatial power spectrum of QSOs, then we compare the result of the analytic approach with a preliminary result of the power spectrum from the two-degree Field QSO redshift (2QZ) survey. From a simple $\chi^2$ test, we show that a finite baryon fraction better explains observation of the QSO power spectrum, which might suggest a possible detection of the baryonic oscillations in the QSO power spectrum.

## 1 Introduction

The 2QZ group has recently reported their preliminary results of the spatial correlation function and the power spectrum. These analyses are based on an initial sample of 10,000 QSOs [1,4]. Numerical simulation is the most common technique through which observational results and theoretical predictions can be compared. Indeed, the 2QZ group has utilized the Hubble Volume simulation, which is a huge N-body simulation of horizon box size, containing 1 billion mass particles run by the Virgo consortium [3]. However, a simple, semi-analytic formula that reproduces numerical results would be useful. The purpose of this paper is to report on the development of such a semi-analytic formula and to apply it to recent observational results. As a demonstration of the usefulness of our approach, we use the formula to place constraints on the cosmological density parameters by comparing the theoretical predictions to the 2QZ power spectrum reported by Hoyle et al. [4].

## 2 Theoretical Formula and a Simple Application

In the clustering statistics of high-redshift objects in a redshift survey, several observational effects must be incorporated for careful comparison between theoretical predictions and an observational result. A useful theoretical formula for the two-point statistics has been developed incorporating the redshift distortions due to peculiar motion of sources and the light-cone effect simultaneously, as well as the geometric distortion [7]. According to the result, the power spectrum is obtained by averaging the local power spectrum $P_0^{\rm a}(k,z)$ over the redshift,

$$P_0^{\rm LC}(k) = \frac{\int dz W(z) P_0^{\rm a}(k,z)}{\int dz W(z)}, \tag{1}$$

with the weight factor $W(z) = \big(dN/dz\big)^2\big(s^2 ds/dz\big)^{-1}$, where $dN/dz$ denotes the number count of the objects per unit redshift and per unit solid angle, and $s = s(z)$ denotes the distance-redshift relation of the radial coordinate that we chose to plot a map of the objects. In the expression (1), $z$-integration arises due to the light-cone effect within the small-angle approximation, and the power spectrum $P_0^{\rm a}(k,z)$ is given by

$$P_0^{\rm a}(k,z) = \frac{1}{c_\perp^2 c_\parallel}\int_0^1 d\mu P_{\rm QSO}\Big(q_\parallel \rightarrow \frac{k\mu}{c_\parallel},\ |\mathbf{q}_\perp| \rightarrow \frac{k\sqrt{1-\mu^2}}{c_\perp}, z\Big), \tag{2}$$

where $P_{\rm QSO}(q_\parallel, |\mathbf{q}_\perp|, z)$ is the QSO power spectrum, $q_\parallel$ ($\mathbf{q}_\perp$) is the wave number component parallel (perpendicular) to the line-of-sight direction in the real space. In equation (2), with the comoving distance in the real space $r(z)$, we defined $c_\perp = r(z)/s(z)$ and $c_\parallel = dr(z)/ds(z)$. We model the power spectrum of Q.SO distribution by introducing the bias factor $b(z)$,

$$P_{\rm QSO}(q_\parallel, |\mathbf{q}_\perp|, z) = b(z)^2\Big\{1 + \beta(z)\Big(\frac{q_\parallel}{q}\Big)^2\Big\}^2 P_{\rm mass}(q,z), \tag{3}$$

where $q = \sqrt{q_\parallel^2 + |\mathbf{q}_\perp|^2}$ and we model the CDM mass power spectrum $P_{\rm mass}(q,z) \propto q^n T(q, \Omega_m, \Omega_B, h)^2 D_1(z)^2$ with the transfer function $T$ and the linear growth rate $D_1(z)$. We adopt the fitting formula of the transfer function by Eisenstein & Hu [2], which is useful when the baryon fraction is large.

As a simple application, we consider a cosmological implication comparing with the power spectrum from a preliminary result of the 2QZ survey. We simply introduce $\chi^2$ defined by

$$\chi^2 = \sum_{i=1}^{17}\frac{\big[P_0^{\rm LC}(k_i) - P^{\rm obs}(k_i)\big]^2}{\Delta P(k_i)^2}, \tag{4}$$

where $P^{\rm obs}(k_i)$ is the observational value at $k_i$ and $\Delta P(k_i)^2$ is the variance of observational errors, for which we adopt the 17 data points in the range $0.012\ h{\rm Mpc}^{-1} < k < 0.2\ h{\rm Mpc}^{-1}$ on Figure 13 in the paper by Hoyle et al. [4]. Figure 1 displays the contours of the $\chi^2$ for various cosmological models on the $\Omega_m - \Omega_b/\Omega_m$ plane. For the clustering bias, we assumed the form $b(z) = b_0/D_1(z)$, where $b_0$ is a constant, which we determined to minimize the value of $\chi^2$. Alternation of this assumption does not alter our conclusion qualitatively. From Figure 1 it is clear that the QSO power spectrum favors the low density universe rather than the standard CDM model with $\Omega_m = 1$. The minimum of the $\chi^2$ is located at $\Omega_m \simeq 0.2 \sim 0.3$ and $\Omega_b/\Omega_m \simeq 0.2 \sim 0.3$. An interesting fact is that the QSO power spectrum is better explained with the finite baryonic component, though the peak of $\chi^2$ is broad and thus the constraint is not that tight [5,6].

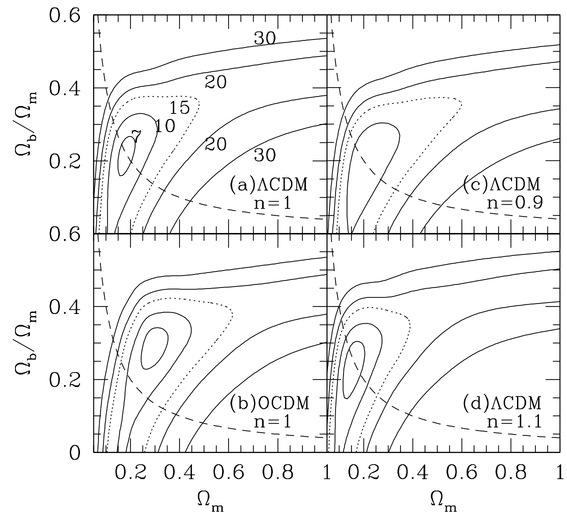


**Fig. 1.** Contours of $\chi^2$ on the $\Omega_m - \Omega_b/\Omega_m$ plane for various cosmological models: (a) The $\Lambda$CDM model with the initial power spectrum with $n = 1$; (b) The open CDM model with $n = 1$; (c) The $\Lambda$CDM model with $n = 0.9$; (d) The same as (c) but with $n = 1.1$. Here the 17 data points in Figure 13 in ref.[4] are used and $b_0$ is determined to minimize $\chi^2$. Levels of the contour curves are $\chi^2 = 7,\ 10,\ 15,\ 20,\ 30$. The dotted line is the contour of the level $\chi^2 = 15$, and $\Omega_b = 0.04$ on the dashed line.

## 3 Conclusion

By performing a simple $\chi^2$ test we have shown that the QSO power spectrum can be consistent with a simply biased mass power spectrum based on the familiar CDM cosmology with a cosmological constant. We have also shown that the finite baryon fraction better explains observation of the 2QZ power spectrum, which might suggest a possible detection of the baryonic oscillations in the QSO power spectrum.

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